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1980
West Fork
Bitterroot
(Painted Rocks)
Dam, Darby,
Montana, Ravalli
County, MT-19

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PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

WEST FORK BITTERROOT (PAINTED ROCKS) DAM DARBY, MONTANA RAVALLI COUNTY MT-19

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PREPARED FOR:

HONORABLE THOMAS L. JUDGE
GOVERNOR, STATE OF MONTANA

STATE OF MONTANA
(OWNER AND OPERATOR)

PREPARED BY:
CH2M HILL
BELLEVUE, WASHINGTON

JULY 1980

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UNITED STATES ARMY CORPS OF ENGINEERS

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DARBY, MONTANA
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EXECUTIVE SUMMARY

Under contract with the Seattle District Corps of Engineers and with representation from the Corps, the State of Montana Department of Natural Resources and Conservation, and the U.S. Forest Service, CH2M HILL inspected West Fork Bitterroot (Painted Rocks) Dam on July 18, 1979, under authority of Public Law 92-367. A return trip was made on November 2 for inspection of the outlet works. The dam is located on West Fork Bitterroot River in Ravalli County, about 22 miles south of Darby, Montana.

This report was compiled from information obtained during an onsite inspection, from review of construction plans, and from analysis of available hydrologic information. Findings were compared with engineering criteria that are currently accepted by most private and public agencies engaged in dam design, construction, and operation.

FINDINGS AND EVALUATION

West Fork Bitterroot (Painted Rocks) Dam is owned and operated by the State of Montana. The dam and reservoir are located on public land administered by the U.S. Forest Service. Painted Rocks Lake is used for recreation and for storage of irrigation waters. Use of National Forest land for such purposes is through special use permits. The 143-foot-high earth dam impounds 45,100 acre-feet at top of dam, elevation 4467.5 feet (local datum). On the basis of criteria in U.S. Army Corps of Engineers "Recommended Guidelines for Safety Inspection of Dams" (Ref. 1), the project is large in size. The dam is located such that its failure would endanger many lives and cause extensive property damage. However, no dam breach analysis or routing of a dam breach flood was made for the downstream area. The conclusions about possible damage are based on a brief field visit and engineering judgment. The project is classified as having a high (Category 1) downstream hazard potential. Inspection criteria (Ref. 1) recommend that the spillway design flood for a large-sized project with a high downstream hazard potential be the probable maximum flood (PMF). The PMF is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region.

An estimated PMF was developed for the 316-square-mile drainage basin. The PMF resulting from the 72-hour general storm has an estimated volume of 162,200 acre-feet and a peak flow of 110,300 c.f.s. The spillway has a maximum discharge capacity of 42,000 c.f.s. (neglecting possible

wall overtopping downstream from the crest) with the reservoir at low point of dam crest, elevation 4467.5 feet (local datum). The routing of the PMF was started assuming the reservoir water surface at spillway crest, elevation 4450 feet (local datum).

Routing studies indicate that:

1. During the full PMF, the dam would be overtopped when approximately 45 percent of the flood volume had entered the reservoir.

2. Routings were made of hypothetical floods less than the PMF to determine the magnitude of floods the dam can contain. The hypothetical hydrographs are obtained by applying percentages to the PMF ordinates. A flood with a hydrograph having ordinates corresponding to 54 percent of the PMF ordinates is just controlled by the project. Larger floods would overtop the dam. However, floods smaller than one-half the PMF may overtop the spillway walls. These flows may erode the dam toe; however, it is unlikely this erosion would lead to dam instability.

The dam is constructed of materials that would quickly erode and rapidly fail when overtopped by floodwaters. A visual inspection of the dam embankment revealed no longitudinal or transverse cracking and no embankment, abutment contact, or toe seepage. No stability analysis of the embankment is on file. Based on a review of available data, the dam embankment may be in conformance with the recommended guidelines; however, its stability cannot be evaluated because of a lack of complete data.

On the basis of the field inspection and study of hydrologic data, West Fork Bitterroot Dam does not now conform to Corps guidelines with respect to discharge and/or storage capacities to safely handle the PMF, leading to potential loss of life and property destruction.

The outlet gates need periodic service to minimize closing friction. The outlet gates are almost impossible to close even under small heads.

RECOMMENDATIONS

Because of storage between normal pool and dam crest, the present project provides a degree of flood protection to the downstream area. The intent of the following report recommendations is to maintain or improve project safety without decreasing this flood protection.

Develop and immediately place in operation a downstream warning plan for use in the event of possible dam overtopping or structural failure. Install piezometers and conduct embankment stability analysis using data obtained from field investigations and laboratory tests. Modify project as studies indicate.

Pull outlet gates and service at regular intervals. Provide means for closing both gates under all head conditions. Inspect outlet works upstream of gates and repair outlet conduit surfaces to minimize cavitation damage. Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity, and modify the project as studies indicate. Conduct studies to determine extent of spillway wall overtopping and protect the embankment from such overtopping. Conduct periodic inspections of the dam at least once every 5 years by engineers experienced in dam design and construction.

Richard L. Foster
Professional Engineer

PERTINENT DATA

1. GENERAL

Federal ID No.	MT-19
Owner	State of Montana
Operator	State of Montana
Date Constructed	1939
Purpose	Irrigation, Recreation
Location	Section 26, T1S, R22W Principal Meridian
County, State	Ravalli County, Montana
Watershed	West Fork Bitterroot River
Downstream Hazard Potential	Category 1 (High)
USGS Quadrangle	Painted Rocks Lake

2. RESERVOIR

Surface Area at Spillway Crest	655 acres
Drainage Area	316 square miles
Storage at Spillway crest, Elevation 4450 feet	32,360 acre-feet
Storage at Dam crest, Elevation 4467.5 feet	45,100 acre-feet
Surcharge Storage	12,740 acre-feet

3. SPILLWAY

Type	Uncontrolled concrete chute with low ogee crest control
Bottom Width	160 feet at crest 60 feet at stilling basin

Crest Elevation	4450 feet
Capacity with Reservoir at Dam Crest	42,000 c.f.s. (However, spillway chute walls may be overtopped at lesser discharges.)

4. OUTLET WORKS

Conduit	10-foot-diameter horseshoe
Conduit Length	580 feet
Gates	Two 5-foot by 8-foot roller gates
Capacity with Reservoir at Dam Crest	3,300 c.f.s.

5. DAM

Type	Rolled earthfill with center impervious core
Length	800 feet
Crest Width	20.5 to 35.5 feet
Crest Elevation	4468 feet (design) 4467.5 feet (actual low point)
Hydraulic Height (Crest to Toe)	143 feet
Upstream Slope (Design and Actual Same)	1 V on 2 H (upper) 1 V on 2.5 H 1 V on 4 H (lower)
Downstream Slope (Design and Actual Same)	1 V on 2 H (upper) 1 V on 4 H (lower)

NOTE: Elevations based on local data.

Chapter 1
BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority and Scope

This report summarizes the Phase I inspection and evaluation of the West Fork Bitterroot (Painted Rocks) Dam, owned by the State of Montana.

The National Dam Inspection Act, Public Law 92-367 dated August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to conduct safety inspections of non-Federal dams throughout the United States. Pursuant to that authority, the Chief of Engineers issued "Recommended Guidelines for Safety Inspection of Dams" in Appendix D, Volume 1 of the U.S. Army Corps of Engineers' report to the United States Congress, National Program of Inspection of Dams, May 1975.

The recommended guidelines were prepared with the help of engineers and scientists highly experienced in dam safety from many Federal and state agencies, professional engineering organizations, and private engineering consulting firms. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community.

Where necessary, the guidelines recommend a two-phase study procedure for investigation and evaluation of existing dam conditions, so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

1. A limited investigation to assess the general safety condition of the dam.

2. Based upon an evaluation of the available data and a visual inspection.

3. Performed to determine if any needed emergency measures and/or additional studies, investigations, and analyses are necessary or warranted.

4. Not intended to include extensive explorations and analyses or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam. Included in Phase II, as required, should be additional visual inspections, measurements, foundation exploration and testing, material testing, hydraulic and hydrologic analyses, and structural stability analyses.

The authority for the Corps of Engineers to participate in the inspection of non-Federally owned dams is limited to Phase I investigations, with the exception of situations of extreme emergency. In these cases, the Corps may proceed with Phase II studies, but only to the extent needed to answer serious questions relating to dam safety that cannot otherwise be answered. The two phases of investigation outlined above are intended only to evaluate project safety and do not encompass in scope the engineering required to perform design or corrective modification work. Recommendations contained in this report may be for either Phase II safety analyses or detailed design study for corrective work.

The responsibility for implementation of these Phase I recommendations rests with the dam owner and the State of Montana. It should be noted that nothing contained in the National Dam Inspection Act, and no action or failure to act under this Act shall be construed (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership or operation of the dam.

1.1.2 Purpose

The purpose of the inspection and evaluation is to identify conditions that threaten public safety, so that they may be corrected in a timely manner by non-Federal interests.

1.1.3 Inspection

The findings and recommendations in this report were based on a brief visual inspection of the project and a detailed review of available construction plans. Inspection procedures and criteria were those established by the "Recommended Guidelines for Safety Inspection of Dams" (Ref. 1).

Personnel present during the July 18, 1979, inspection included:

Miles C. Bubenik, CH2M HILL
Jerry Jacksha, CH2M HILL
Loren Bottorff, CH2M HILL
Captain Don Warner, Seattle District, U.S. Army Corps of Engineers
Art Taylor, State of Montana Department of Natural Resources and Conservation
Alex Bailey, State of Montana Department of Natural Resources and Conservation
Ron Volden, U.S. Forest Service
Dick Judge, U.S. Forest Service

Personnel present during the November 2, 1979, inspection included:

Jim Fuller, CH2M HILL
Loren Bottorff, CH2M HILL
Richard Eckerlin, U.S. Army Corps of Engineers
Art Taylor, State of Montana Department of Natural Resources and Conservation
Jeff Duus, State of Montana Department of Natural Resources and Conservation
Ron Volden, U.S. Forest Service

CH2M HILL personnel who participated in the field inspection and contributed to this report are:

Miles C. Bubenik, Geotechnical Engineer, Team Leader
Jerry Jacksha, Geotechnical Engineer
Jim Fuller, Civil Engineer
Loren Bottorff, Hydrologist/Hydraulics Engineer

This report has been reviewed by the State of Montana and the U.S. Forest Service; their written comments are enclosed at the end of the report.

1.2 DESCRIPTION OF PROJECT

1.2.1 General

West Fork Bitterroot (Painted Rocks) Dam is located on the West Fork Bitterroot River, approximately 22 miles south of Darby (see Plate 1). The dam has a high downstream hazard potential, and the Federal identification number is MT-19. The 143-foot-high, 800-foot-long dam, completed in 1939, impounds 45,100 acre-feet at crest, actual elevation 4467.5 feet (local datum). Based on a visual reconnaissance and engineering judgment, a campground, a Job Corps work center, a U.S. Forest Service ranger station, and approximately 15 homes could be affected by a sudden breach of the dam. The town of Darby may also be affected by a breach of the dam. On the basis of this information and in accordance with the recommended guidelines, the project size is large, and the downstream hazard potential is high (Category 1).

The 655-acre reservoir is used for recreation and storage of irrigation water. The project is owned and operated by the State of Montana.

The 160-foot-wide and 360-foot-long uncontrolled spillway is located on the right abutment (Photo 1 and Plate 2). A 10-foot-diameter horseshoe-shaped outlet with two 5-foot by 8-foot roller gates (with controls at the dam crest) is located through the right abutment of the dam.

1.2.2 Regional Geology and Seismicity

The regional geology and seismicity were addressed in a memorandum by R. D. Eckerlin (Ref. 2). The following information is taken from that memorandum.

> Painted Rocks Lake lies on the West Fork of the Bitterroot River on the eastern front of the Bitterroot Range within the Northern Rocky Mountains physiographic province. The Bitterroot Range is composed mostly of late Cretaceous igneous rock of the Idaho Batholith. Painted Rocks Reservoir lies within the border zone area between granitic rocks and metaquartzites correlative with the Ravalli Group. Within this zone, the granite rocks are mixed with dike rock and metamorphic host rock forming local migmatite assemblages.
>
> A zone of major left lateral translation known as the Lewis and Clark Line, a part of the Montana Lineament, tectonically divides the Northern Rocky Mountains into a Northern and a Southern Province. Painted Rocks Dam lies about 85 miles south of the Lewis and Clark Line in a region of extremely varied and complex geology. Structural features in the region are a series of nearly parallel thrust faults which trend in an east-southeast direction and which cut across older structures of the Laramide deformation having a north-south trend. Thrust faulting is the dominant type of rock failure in the region and is assumed to have been caused by north-northeastward directed forces. Evidence of Pleistocene alpine glaciation can be seen in the Bitterroot Range in the form of cirques, moraines, and glacial debris extending down the valleys.
>
> The dam lies in a seismically quiet zone adjacent to the Bitterroot Valley. The Seismic Zone Map of Contiguous States, shown in the "Recommended Guidelines" (Ref. 1) indicates the dam is in Zone 2. Although the region is one in which a moderately damaging earthquake should be expected, historic seismicity indicates minor risk. Algermissen (Ref. 3) estimates a 90 percent probability of 0.04 percent g acceleration not being exceeded in 50 years.

1.2.3 Site Geology

The boring logs and dam embankment profile (Plate 3) indicate that the foundation is consolidated sandy gravel with boulders over decomposed granite that in turn overlies solid granite. There is no foundation geologic report on file. Available plans indicate that a cutoff trench to solid granite rock probably exists under much of the dam embankment. Construction photos on file show that both abutment contacts were stripped of overburden and that grooves or

notches were cut into the granite. The exposed granite on the abutment (Photo 2) appears to be massive. The right abutment rock was covered except for an outcrop near the spillway (Photo 3).

The spillway is excavated through the right abutment and consists of a concrete-lined channel founded on granite for its entire length. Grouted rock anchors were placed 4 feet into rock along the spillway. The stilling basin is lined with concrete; based on slab details, the basin is founded on rock for approximately the half of the basin nearest the spillway and probably on thicknesses up to 6 feet of sandy gravel for the remainder of the basin.

The 10-foot-high, horseshoe-shaped concrete conduit is located in the right abutment. For the upstream 206 feet, the conduit is founded on gravel and decomposed granite. The remaining 374 feet to the portal is concrete-lined tunnel through the granite. Plans indicate the control tower at the dam's west end is also founded in the solid granite.

1.2.4 Design and Construction History

The West Fork Bitterroot (Painted Rocks) project was designed in 1938 and 1939 by the State of Montana Water Conservation Board. Construction for the State Water Conservation Board began in 1939 and was completed in 1940. In 1976, Harza Engineering Company designed outlet works, conduit, and gate modifications. The original drawing and revised drawings are on file with the State of Montana. In addition, construction photographs and inspection summaries, with some soil quality control tests during construction, were on file for review. No construction specifications, strength tests, or stability analyses are on file.

Chapter 2
INSPECTION AND RECORDS EVALUATION

2.1 HYDRAULICS AND STRUCTURES

2.1.1 Spillway

The spillway for West Fork Bitterroot (Painted Rocks) Dam is located in the right abutment and is founded in granite rock for its entire length. The unlined approach channel to the uncontrolled concrete ogee-shaped crest is approximately 100 feet long and is crossed by a log boom. The crest discharges to a concrete chute, which ends at a stilling basin about 10 feet below creek level.

The concrete crest is formed in an ogee shape of approximately 12-foot design head. The apex of the spillway crest is at elevation 4450 feet (local datum)--17.5 feet below the low point on the dam crest. The spillway crest is 160 feet wide and contains two 2.5-foot-wide bridge piers, which reduce the net spillway width to 155 feet. Downstream of the crest, the spillway chute narrows to a 100-foot width within a distance of 74 feet and to a 66-foot width within an additional 60 feet (see Plate 4 and Photo 4). The chute continues for approximately another 63 feet to the stilling basin (final chute width is 60 feet). The slope of the chute gradually changes from .087 downstream of the crest to 1.449 at the stilling basin. The outlet tunnel portal is located on the face of the spillway chute, 17.5 feet above the floor of the spillway(Plate 4 and Photo 4). The concrete of the spillway chute contained some cracking and spalling, but in general was in good condition. Grouted rock anchors were placed 4 feet into rock along the spillway. The left spillway wing wall showed some tilting at the construction joint; joint material was in place, and no embankment materials were being lost through the joint.

The stilling basin is lined with concrete and is about 150 feet long. Plans show that the basin is founded on rock for about half its length (nearest the spillway) and up to 6 feet of sandy gravel for the remaining length. The stilling basin floor is at two elevations; the 52-foot length nearest the spillway is 10 feet lower than the stream channel, and the remaining length is 4 feet lower than the stream channel. The width diverges from 60 feet to 125 feet. One row of chute blocks is located at the end of the spillway chute, and three rows of baffle piers are located just downstream in the stilling basin (Plate 4). The baffle piers are aligned towards the outlet tunnel, which is oriented about 20 degrees from the centerline of the spillway chute. A baffle wall crosses the stilling basin 52 feet downstream from the beginning of the basin, separating the two elevations

of the floor. The wall is 11.5 feet high in the center and 9.5 feet high on either end. The end of the stilling basin has 50-foot-long wing walls oriented perpendicular to the direction of flow. The sides of the downstream channel are heavily riprapped and show no signs of erosion or back-cutting. At the time of the inspection, the stilling basin was full of water, so the condition of the concrete surfaces could not be observed.

The spillway discharge rating was developed by using the weir head-discharge relationship, with the head-dependent discharge coefficients varying from 3.23 to 4.04. The coefficients are for an ogee crest with a crest height to design head ratio of 0.33. The maximum discharge capacity of the spillway was estimated to be 42,000 c.f.s. with the reservoir at the top of the dam, elevation 4467.5 feet (local datum). However, the chute walls downstream from the crest may be overtopped at flows significantly less than this discharge because the quickly converging chute may initiate wave action in the chute. Flows near the maximum spillway capacity may impinge on the bottom of the spillway bridge at the left (looking downstream) side of the bridge. The estimated discharge rating curve is presented on Plate 5.

A model study of the spillway and stilling basin was performed before construction. The model was built on a scale of 1:49. The design report (Ref. 3) concentrates mainly on the performance of the stilling basin. No rating curve was provided, but the report does state that the spillway is capable of discharging 30,000 c.f.s. (probably with the 13-foot design head that is mentioned). This 30,000 c.f.s. agrees fairly closely with the 29,000 c.f.s. obtained from estimates (Plate 5) during this dam safety study, with 13 feet of head. The report gives no specific numbers relating to the wave action from the converging chute, but does make the following general statements that this effect did cause a change in the design of the stilling basin baffle wall:

> Another observation made while conducting tests was that due to narrowing of the chute below the crest, the water had a tendency to pile against the walls creating a larger depth than anticipated. Upon being deflected, the deep streams from either side coalesced in the middle of the lower part of the chute as can be seen in some of the photographs. The water being deeper at the center than at the sides, it was necessary to build the baffle wall in the stilling basin higher through the middle than at the side. This could have been partly corrected by building the floor of the chute higher in the middle than at the sides, thus deflecting the

water; however, time did not permit making experiments along this line as the contractor was ready to build this section of the spillway and could not be delayed.

Apparently, the model spillway chute walls did not overtop during a scaled 30,000 c.f.s. discharge. However, since the spillway can pass 42,000 c.f.s., a discharge of 40 percent greater than that model studied, it is likely that the chute walls will be overtopped before this maximum discharge is reached. Water marks observed on the chute walls during the site visits indicate that the wave action in the chute concentration has been substantial for historical discharges. Overtopping of the left spillway chute wall would cause water to erode the embankment toe; however, it is unlikely this erosion would lead to dam instability. Also, the stilling basin was designed for 30,000 c.f.s. and may not be adequate for the maximum discharge of 42,000 c.f.s.

2.1.2 Outlet

The outlet works for West Fork Bitterroot Dam is located in the right abutment of the dam. The intake structure consists of a 30-foot-high concrete tower with trash racks on the tower top and on three sides. The gross area covered by the trash racks is 472 feet. It is not known if a 14-foot by 10-foot opening near the tower bottom is covered with a trash rack since this opening was below reservoir level during both site visits. The invert elevation at the conduit entrance is 4330 feet (local datum).

The concrete conduit is a 10-foot-diameter horseshoe section approximately 580 feet in length (Plate 6). The upstream 206 feet of conduit is founded on gravel and decomposed granite, and the remaining 374 feet is concrete-lined tunnel section through granite. Originally, construction of the intake structure was started 82 feet upstream from the beginning of the tunnel section. At that time, a decision was made to build a higher dam and an additional 124 feet of conduit, and a new intake structure had to be constructed. The original 82 feet of conduit was reinforced for the greater height of dam by placing a continuous 1-foot-thick concrete column down the center of the conduit. A wet well gate tower is located about 340 feet downstream from the intake structure near the centerline of the dam. Plans indicate the control tower is founded in granite rock. The controls for the two 5-foot by 8-foot roller gates (one operating and one emergency gate) are located at the top of the tower and are protected from weather by a building (see Photo 1).

The transition downstream of the operating gate experienced severe cavitation damage in 1975 when the outlet was used to discharge high flood flows. A portion of a 1975 memo by Richard Regan (Ref. 4) of the Corps of Engineers describes some of this damage:

> Severe damage was observed throughout the transition area between the gate and the tunnel. Portions of the steel liner are missing and cavitation processes have removed concrete from the walls and floor up to 10 and 13 inches deep, respectively. The concrete in the floor of the tunnel near the transition has been completely removed to the foundation rock, and the cavitation processes are now attacking the rock. Open cavities between the concrete of the tunnel floor and the foundation rock were noted. Mr. Bailey stated he previously had inserted a steel tape into one of these cavities for a distance of approximately 13 feet.

The basic problems were that the 6-inch-diameter vent pipe was of insufficient size to satisfy the air demand with the high discharges experienced in 1975, and the transition geometry between the operating gate and downstream tunnel resulted in conditions having a high potential for initiating cavitation damage. A new transition and 42-inch-diameter corrugated steel vent pipe (Plate 6) were constructed in 1977 downstream of the operating gate to minimize cavitation damage potential. Downstream of the transition, the conduit extends approximately 220 feet to the exit portal located within the spillway chute. The invert of the conduit at this point is 4329.5 feet (local datum), 17.5 feet above the floor of the stilling basin. A 3-foot-high baffle at the end of the outlet conduit was removed in 1977 to allow additional venting along the crown of the tunnel.

During the July 18, 1979, site visit, with the reservoir near spillway crest (approximately 120 feet of head), several attempts were made to seal the operating and emergency gates. Approximately 50 to 100 c.f.s. continued to be discharged with minimum gate settings. During the November 2, 1979, site visit, with near empty reservoir (approximately 25 feet of head), the emergency gate was sealed, and the conduit was entered from the downstream portal. The tunnel concrete contained some minor cracking and erosion but, in general, was in very good condition. The new transition area appeared in very good condition, with no evidence of cavitation damage. The downstream edges of the epoxy material on the tunnel floor (about 30 feet downstream of gates) were broken and could initiate cavitation damage. The emergency gate was leaking an estimated 20 to 30 gallons per minute (gpm). The operating gate is in generally good condition, but the paint on the gate is poor.

The stainless steel seats put on the gate in 1974 are in excellent condition, with no sign of erosion, corrosion, or damage from cavitation. The bronze seating surfaces in the gate frame show wear associated with cavitation. The roughened surface will prevent a good seal with the newer stainless steel seats on the gate.

The rollers visible at the gate bottom were rusty, with pits up to 1/8 inch deep. The rollers and roller chain did not rotate during the gate operation, indicating that they are partly or wholly frozen; the rollers may turn when the gate has pressure of a full reservoir, but they could not be turned by hand. The roller guides (races) are irregularly rough and rusty. Some of the irregularity appears to be the result of cyclic rubbing of the rollers against the guides, possibly as a result of gate vibration from up-and-down elastic action of the supporting cables and hammering action between the upstream and downstream roller guides during the cavitation that damaged the tunnel in 1975.

The operating gate is about 3/4 inch narrower than the frame. The gate "wedges" from side to side when it is raised or lowered, but the gate height (8 feet) prevents this action from adding significantly to the operating friction. The lift mechanism worked smoothly and appears well maintained. However, the cable between the lift and the gate was not inspected. The gate operator has no positive means of knowing when the gates are lifted to full opening. During the site visit, the operator lifted the operating gate to what he thought was the fully open position. However, the gate could have been raised another 2 feet.

The discharge rating for the outlet works was developed with both gates fully open. A Manning's "n" of 0.013 was used to estimate friction losses with the conduit flowing full. The maximum discharge capacity of the outlet works, with the reservoir at the top of dam, elevation 4467.5 feet (local datum), was estimated to be 3300 c.f.s. Any interference from spillway discharges was neglected.

2.1.3 Freeboard

Because the dam overtops during the PMF (see section 2.2.4), it has no freeboard with the recommended spillway design flood. The vertical distance between the low point on the dam and the reservoir at the time of the July 18, 1979, inspection was 18 feet. The vertical distance between the low point on the dam and the reservoir at the time of the November 2, 1979, inspection was about 122 feet. The spillway crest is 17.5 feet below the low point on the crest of the dam. The crest of the dam varies 1.5 feet in elevation over its 800-foot length. The effective fetch for wind-generated waves is about 0.6 of a mile, and wave runup on the embankment

is estimated to be about 3.5 feet. Although the dam will overtop during the PMF, the vertical distance between the crest of the dam and the normal reservoir level is adequate to prevent overtopping of the embankment by wind waves during normal operating conditions.

2.2 HYDROLOGY, CLIMATOLOGY, AND PHYSIOGRAPHY

2.2.1 General

The climate of the area is modified continental, characterized by warm summers, cold winters, and a semiarid precipitation regime. The nearest climatological station with long record (elevation 3880 feet) is at Darby, about 22 miles north of West Fork Bitterroot Dam. Mean annual precipitation at the station is 16 inches, with 31 percent falling from April through June. Mean March precipitation is 0.99 inch, and mean June precipitation is 2.06 inches. Mean annual precipitation on the West Fork Bitterroot Dam drainage basin is probably near 25 inches. Mean annual temperature at Darby is 45.2 degrees Fahrenheit (F). Mean January temperature at Darby is 25.8 degrees F, and mean July temperature is 65.1 degrees F. Temperatures on the West Fork Bitterroot drainage basin may average about 15 degrees cooler than Darby. Occasionally, summer temperatures exceed 100 degrees F and winter temperatures dip below -40 degrees F.

The drainage basin area for West Fork Bitterroot Dam is 316 square miles, roughly rectangular in shape, and west of the Continental Divide. Basin elevations range from 4740 feet NGVD at the dam to 8909 feet NGVD on the southeastern boundary of the basin. The basin is steep and heavily forested. The lake is supplied by several inflow streams, but the West Fork Bitterroot River drains approximately 80 percent of the basin. A USGS stream gaging station (1941 to present) is located on the West Fork Bitterroot River about 2,000 feet downstream of the dam. A maximum discharge of 4,060 c.f.s. occurred on May 9, 1947. Average discharge is 292 c.f.s., 0.92 c.f.s. per square mile.

An excerpt from the spillway model study report (Ref. 3) follows:

> While the crest is capable of discharging 30,000 c.f.s., it is not expected that a flood of more than 26,000 c.f.s. will ever occur. This is in line with the U.S. Reclamation Service estimate for this drainage area. The drainage area is 312 square miles and the discharge provided for is 83.5 c.f.s. per square mile or a Meyers coefficient of 1,470.

2.2.2 Reservoir Storage and Spillway Discharge

The reservoir has a surface area of 655 acres and a storage of 32,360 acre-feet at spillway elevation 4450 feet (local datum). Approximately 12,740 acre-feet of surcharge storage is available in the reservoir between spillway crest and the dam crest. The spillway discharge with the reservoir at the dam crest is 42,000 c.f.s., about 3,500 acre-feet per hour.

2.2.3 Estimated Probable Maximum Flood

The inspection guidelines recommend that the spillway design flood (SDF) for a project of this type be the probable maximum flood (PMF). The PMF is the flood expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. An estimate of the PMF was made during this dam safety analysis and was routed through the reservoir. Procedures available for the area west of the Continental Divide allow for development of a probable maximum precipitation (PMP) from a thunderstorm or a general storm. Because of the size of the West Fork Bitterroot Dam drainage basin, a general storm was believed to cause the most critical flood.

The procedures contained in the U.S. Weather Bureau's Hydrometeorological Report No. 43 (Ref. 5) and the Weather Bureau's 1967 memo (Ref. 6) were used to compute the PMP. The memorandum allows for some reduction of the PMP that was not originally contained in Report No. 43. The general storm produces 2.88 inches in 6 hours and 8.25 inches in 72 hours.

Frozen ground and no infiltration losses were assumed during the entire flood. A base flow of 3,000 c.f.s. was used for the entire flood.

A triangular unit hydrograph for a 30-minute rainfall duration was developed for the 316-square-mile drainage basin by procedures outlined in Design of Small Dams (Ref. 7). A curvilinear fit of the triangular unit hydrograph was used. The PMP was applied to the unit hydrograph by means of the computer program HEC-1 (Ref. 8). This estimate of the PMP produced a flood with a peak flow of 110,300 c.f.s. and a volume of 162,200 acre-feet.

2.2.4 Flood Routing

The PMF was routed through the reservoir by using the computer program HEC-1 (Ref. 8). The reservoir was assumed to be at the spillway crest at the beginning of the PMF. The outlet works was assumed to be fully open during the entire flood. The routing shows that the dam will be overtopped during the PMF when approximately 45 percent of the total flood volume enters the reservoir. The dam does not overtop

during a flood that has ordinates of 54 percent of the PMF hydrograph. The spillway chute walls may be overtopped during smaller floods; however, it is unlikely this erosion would lead to dam instability. This routing, with the outlet works fully open, shows the best performance of the project. Routings with the outlet works closed will show the dam overtopping at a lesser percentage of the PMF.

2.3. GEOTECHNICAL EVALUATION

2.3.1 Dam Embankment

The 143-foot-high, curved-axis earth, gravel, rockfill embankment is 800 feet long and has a crest width varying from 21.5 to 35.5 feet. Upper portions of the upstream and downstream slopes are 1 V on 2 H, and lower portions are 1 V on 4 H (Plate 3). The upstream and downstream slope of the central impervious to semi-impervious core is 1 V on 1.5 H. Sand, gravel, and rock toe berms, upstream and downstream, are sloped at 1 V on 4 H.

No specifications were on file; however, construction photographs show that fine-grained central core material was compacted with sheepsfoot rollers. Size and placement techniques used for the upstream and downstream rock and gravel toe berms are unknown.

Visual inspection found that the downstream embankment slope is sandy gravel and rockfill, with a very sparse covering of grass and brush (Photo 5). The upstream slope (Photo 6) is adequately protected from wave erosion by a blanket of riprap estimated to be 2 feet thick. Some minor wave erosion has occurred at the right end of the dam along the curved section, but it does not endanger stability of the upstream slope. No other significant erosion, irregularity, slumps, or cracks were found on the dam crest or slopes.

2.3.2. Foundation Conditions, Seepage, and Drainage

Both abutments of the dam are granite rock. The plans (Plates 2 and 3) show that several cutoff grooves were designed for both abutments. These grooves were to be excavated within the boundaries of the cutoff trench, with the dimensions about 8 feet deep and 25 feet wide, according to the detail on Plate 3. It is presumed that these grooves were intended to increase the effectiveness of the cutoff trench. Construction photos of both abutments during embankment fill placement showed some of these grooves. The cutoff trench under the central impervious core was carried to rock, "except for a narrow channel under the old river bed" (Ref. 8). Progress reports (Ref. 9) stated that cutoff trench backfilling was done by the puddle method (approximately 12-inch layers of earth, sand, and gravel deposited

in water and thoroughly worked with shovels). At the base of the dam, starting at the right abutment, plans (Plate 3) show that a concrete cutoff wall 10 feet high was constructed into the rock foundation, extending from the cutoff grooves to the spillway; its alignment is slightly upstream of the dam centerline. It is not known how the remaining foundation for embankment fill was prepared.

During the July 18, 1979, inspection, with the reservoir level 18 feet below dam crest, no seepage or erosion from past seepage was observed on the embankment or abutment contacts. Some spillway seepage, approximately 5 g.p.m., was flowing clear from weep holes near elevation 4442 and from construction joints in the lower spillway at about elevation 4335.

The dam embankment contains no known piezometers. No mention is made or location shown for the drain trench that is detailed on Plate 3.

The embankment does not have an internal drainage system.

2.3.3 Stability

Guidelines for dam safety inspections (Ref. 1) recommend that stability analyses be on file for all dams in the high hazard category, and that the safety factor for the steady state seepage conditions be 1.5 or greater. Based on a review of available information, embankment stability may be in conformance with the recommended guidelines. However, because of the lack of strength data, material and classification test data, piezometers, and detailed description of construction procedures, the embankment stability cannot be evaluated.

2.4 PROJECT OPERATIONS AND MAINTENANCE

The facility is owned by the State of Montana and is operated by the State of Montana Department of Natural Resources and Conservation (DNRC). Information about operations and maintenance was obtained from discussions with Mr. Alex Bailey, dam operator, since formal project operation and maintenance programs for the dam do not exist. Mr. Bailey's office is in Hamilton.

2.4.1 Dam

Maintenance of the dam is performed as required. Extensive repairs were made to the gates and tunnel in 1974. Extensive cavitation destroyed the repairs and caused further damage to the tunnel immediately downstream of the gates in 1975. This damage was repaired by construction of a new transition and air vent shaft to minimize cavitation potential; however, both gates require repairs to enable

complete closure of the outlet conduit. Overall, the project appeared to be very well maintained.

The State of Montana DNRC conducts annual inspections of the facility and makes appropriate repairs as needed.

2.4.2 Reservoir

The dam is visited often by Mr. Bailey or one of his staff members. The dam was built for irrigation water storage, but no water users' association developed. The State of Montana Department of Fish and Game (DFG) buys 5,000 acre-feet of water per year. Water is also sold to one landowner on a temporary contract. There is no formal reservoir operating plan, and reservoir releases are based on Mr. Bailey's experience and judgment. Usually, the emergency gate is fully raised, and releases are regulated with only the operating gate. Gate vibrations occur when both gates are partially open. Gate openings are made and releases are checked at the USGS stream gaging station below the dam. An attempt was made in 1975 to operate the reservoir for flood control. However, peak flows were not materially affected because of the large drainage area and the rapid rate of reservoir filling. The spillway normally operates each year, but according to Mr. Bailey, the pool can be lowered below the spillway crest within a few days by increasing the outlet discharge.

2.4.3 Warning System

There is no formal warning plan for use in the event of impending dam failure.

CHAPTER 3
FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Visual inspection of the dam, supplemented by analysis of the project in terms of the recommended guidelines performance standards, resulted in the following findings.

3.1.1 Size, Hazard Classification, and Safety Evaluation

In accordance with inspection guidelines, West Fork Bitterroot Dam is large in size and, based on our visual inspection and judgment, it has a high downstream hazard potential. The guidelines' recommended spillway design flood (SDF) for projects of this type is 100 percent of the PMF. Based on reconnaissance-level investigations and preliminary analyses, the project is only capable of handling a flood having 54 percent of PMF ordinate. Overtopping with subsequent dam failure could occur, which, in our judgment, would seriously jeopardize life and property downstream. West Fork Bitterroot Dam does not meet inspection guideline criteria.

3.1.2 Embankment Dam

A visual inspection of the dam revealed no longitudinal or transverse cracking and no embankment, abutment contact, or toe seepage. Seepage, which does not affect embankment stability, was noticed from weep holes and construction joints in the spillway slab.

The upstream and downstream slopes were uniform, with no irregularities or slumps. The downstream slopes support a very sparse covering of grass and small brush. Riprap on the upstream slope adequately protects against erosion, and the normal freeboard is adequate to prevent wind-generated waves from overtopping the dam crest.

No stability analysis of the dam embankment is on file. No piezometric levels, gradation or strength tests of the various materials actually used in embankment construction are available. Based on a review of available data, the dam embankment may be in conformance with the recommended guidelines; however, its stability cannot be evaluated.

3.1.3 Spillway and Reservoir Capacity

The reservoir has a surface area of about 655 acres at spillway crest elevation, 4450 feet (local datum). Approximately 12,740 acre-feet of surcharge storage is available in

the reservoir between the spillway crest and the dam crest. The discharge of the spillway, with the reservoir at the dam crest, is 42,000 c.f.s., about 3,500 acre-feet per hour. Spillway discharges less than this maximum flow may overtop the spillway chute walls and cause erosion of the dam toe; however, it is unlikely this erosion would lead to dam instability.

3.1.4 Outlet Works

The conduit between the intake structure and the emergency gate could not be inspected because it was full of water. The gates are almost impossible to close against even small heads; therefore, emergency closure of the outlet is improbable. The operating gate and the downstream side of the emergency gate were inspected during the November 2, 1979, site visit. The gates appeared in generally good condition, but friction from the poor rollers adds to the difficulty of closing the gates. The seats in the gate frame are pitted. The emergency gate was leaking an estimated 20 to 30 gpm. Both gates need complete servicing on a routine basis. The new transition area constructed in 1976 appeared in very good condition, with no evidence of cavitation damage.

The outlet exits on the spillway face (Photo 4). Simultaneous outlet/spillway operation may cause low pressures and result in cavitation potential at the exit portal and spillway face immediately below the exit.

3.1.5 Operation and Maintenance

Maintenance of the dam is performed as required. The State of Montana DNRC conducts annual inspections of the facility and makes appropriate repairs as needed. The dam is visited often by Mr. Bailey, dam operator from Hamilton, or by one of his staff members. There is no formal reservoir operating plan, and reservoir releases are based on Mr. Bailey's experience and judgment. There is no formal warning plan for use in the event of impending dam failure.

3.2 RECOMMENDATIONS

Because of storage between normal pool and dam crest, the present project provides a degree of flood protection to the downstream area. The intent of this report's recommendations is to maintain or improve project safety without decreasing this flood protection. The findings suggest that high priority be given to the following recommendations:

1. Immediately develop, implement, and periodically test an emergency warning plan for use in the event of impending dam overtopping or structural failure.

2. Pull gates and service at regular intervals; this may include replacement of rollers and roller chair, seals, and roller races.

3. Provide means for closing both outlet gates under all head conditions.

4. Conduct a study of the cavitational potential of the outlet exit portal during periods of simultaneous spillway-outlet discharge. Modify operational procedures as studies indicate.

5. Inspect outlet works upstream of gates. Throughout outlet conduit, repair surfaces to minimize cavitation damage.

6. Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity; modify the project as studies indicate.

7. Conduct studies to determine extent of spillway wall overtopping and protect the embankment from such overtopping. Determine adequacy of stilling basin for expected flows. Consider possible interference of bridge at maximum discharge.

8. Conduct, and place on file, stability and seepage analyses of the dam embankment. These analyses must be performed by a qualified geotechnical engineer and based on seismic and static loading conditions; in situ strength properties of the embankment, foundation, and abutment materials; and phreatic surface conditions. The material strength properties must be established by drilling and sampling with laboratory testing, as appropriate, and the phreatic surface must be obtained by installing and monitoring piezometers. Modify the project, if studies indicate, to bring the embankment stability into conformance with the inspection guidelines.

9. Conduct periodic inspections of the dam at least once every 5 years by engineers experienced in dam design and construction.

REFERENCES

1. U.S. Army Corps of Engineers, Office of the Chief of Engineers Report to the U.S. Congress, National Program of Inspection of Dams, Vol. 1, Appendix D, "Recommended Guidelines for Safety Inspection of Dams," Washington, D.C., Department of the Army, May 1975.

2. Richard D. Eckerlin, Seattle District U.S. Army Corps of Engineers, "Memorandum on Painted Rocks Dam Geology Inspection," August 1979.

3. Sahinen, Geo. F., "West Fork of Bitterroot Project, Ravalli County, Report on Model Spillway Tests."

4. Regan, Richard P., MEMO: "Report on Inspection Related to Cavitation Damage of the Outlet Tunnel at Painted Rocks Dam," Seattle District U.S. Army Corps of Engineers, November 24, 1975.

5. U.S. Weather Bureau, Hydrometeorological Report No. 43, "Probable Maximum Precipitation, Northwest States," Washington, D.C., 1966.

6. U.S. Weather Bureau, Office of Hydrology, MEMO: "Probable Maximum Precipitation, Northwest States," August 21, 1967.

7. U.S. Bureau of Reclamation, Design of Small Dams, 2nd Edition, 1974.

8. U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-1 Flood Hydrograph Package, Davis, California, 1973.

9. State of Montana, Support Data Progress Reports, West Fork Bitterroot Storage Project, September 1939 to November 1940.

APPENDIX

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

THOMAS L. JUDGE, GOVERNOR
32 SOUTH EWING

STATE OF MONTANA

(406) 449-2872
HELENA, MONTANA 59601

June 11, 1980

Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, WA 98124

Attn: Ralph Morrison

Re: CH_2M Hill Dam Safety Inspection Report on West Fork Bitterroot (Painted Rocks) Dam (MT-19).

Dear Ralph:

We have reviewed the above referenced final draft report. We concur with the findings and recommendations and find that it satisfies the criteria of the Phase I report.

Minor editorial comments have been discussed with your staff, and we understand these will be incorporated in the final report.

Thank you for this opportunity to review and comment on the final draft report on West Fork Bitterroot (Painted Rocks) Dam.

Sincerely,

Richard L. Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau
(406) 449-2864

RB/AT/mb

AN EQUAL OPPORTUNITY EMPLOYER

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FEDERAL BUILDING MISSOULA, MONTANA 59801

JUN 2 0 1980

Mr. Sidney Knutson, P.E.
Department of the Army
Seattle District, Corps of Engineers
P. O. Box C-3755
Seattle, Washington 98124

Dear Mr. Knutson:

We have reviewed the draft report of the Painted Rocks Dam and agree with the report recommendations.

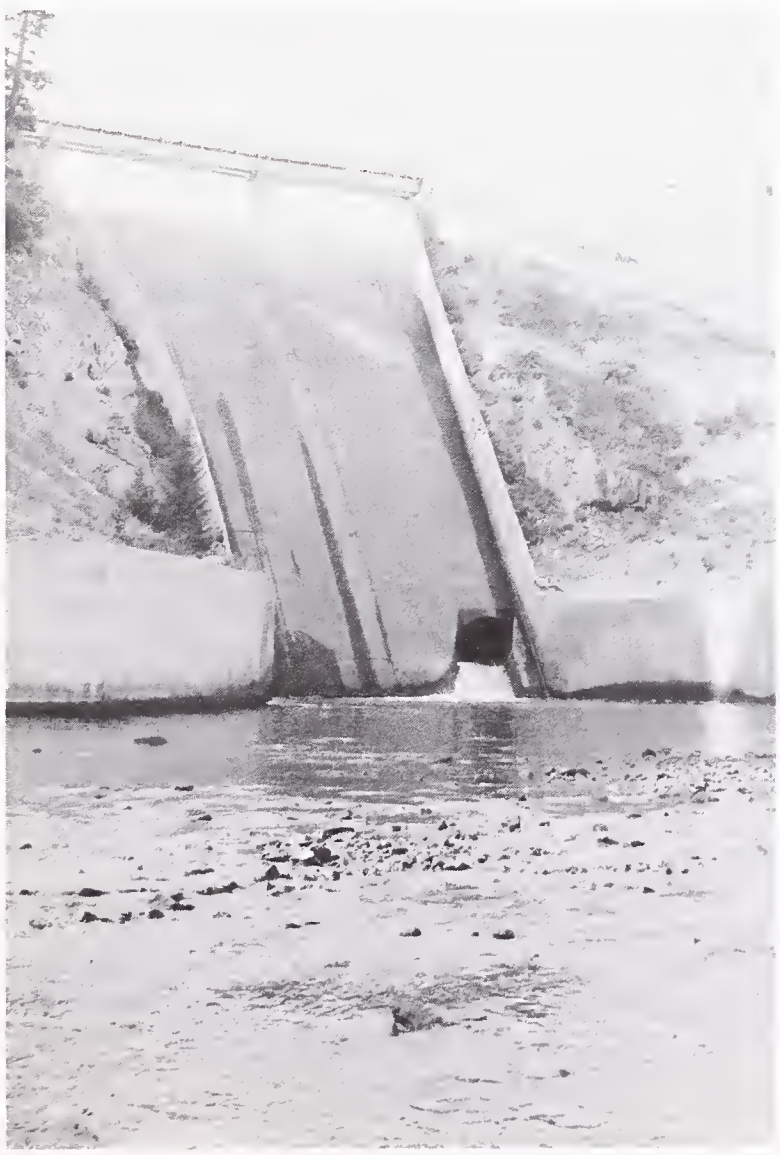
R. W. LARSE
Director
Engineering

cc: Bitterroot NF

(PHOTO 1) SITE VIEW OF DAM FROM RIGHT ABUTMENT.
NOTE SPILLWAY BRIDGE AND GATE HOUSE.

(PHOTO 2) LEFT ABUTMENT ROCK

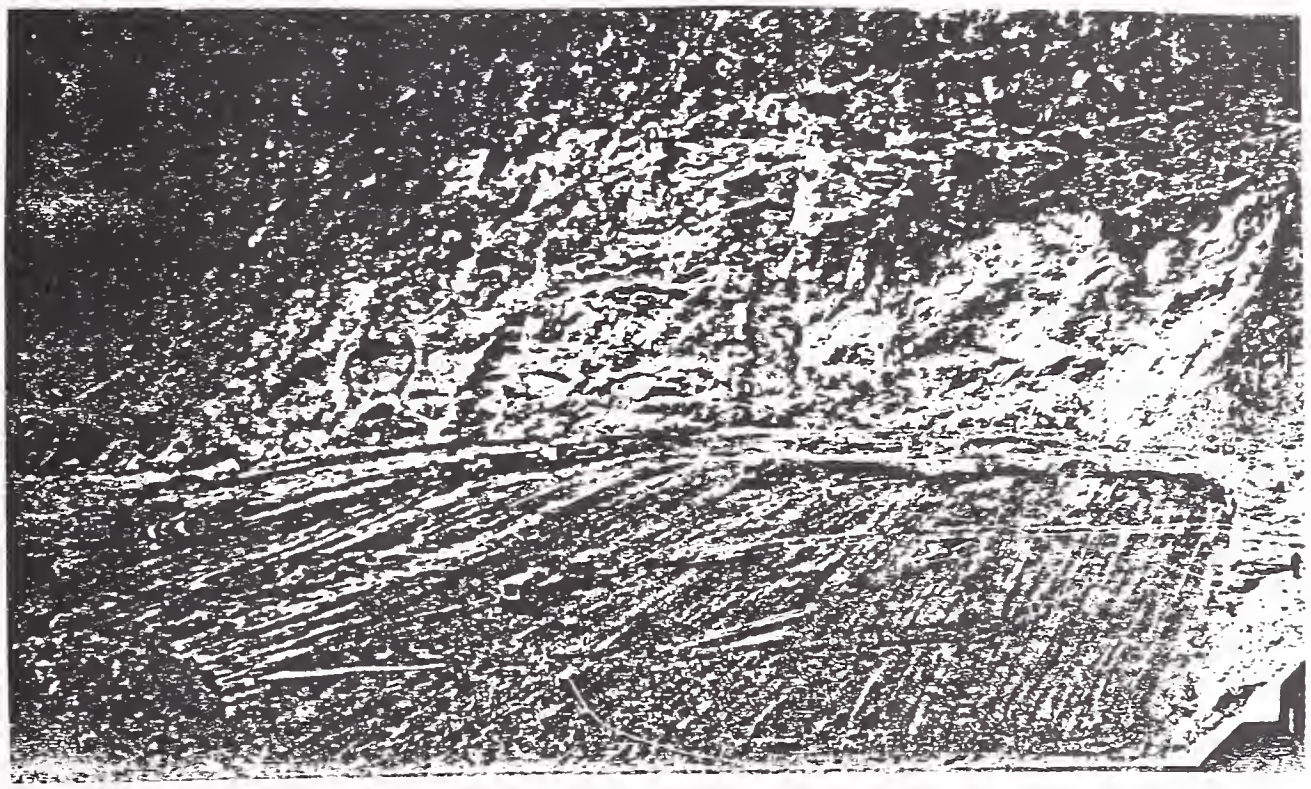
(PHOTO 3) RIGHT ABUTMENT OUTCROP



(PHOTO 4) SPILLWAY CHUTE

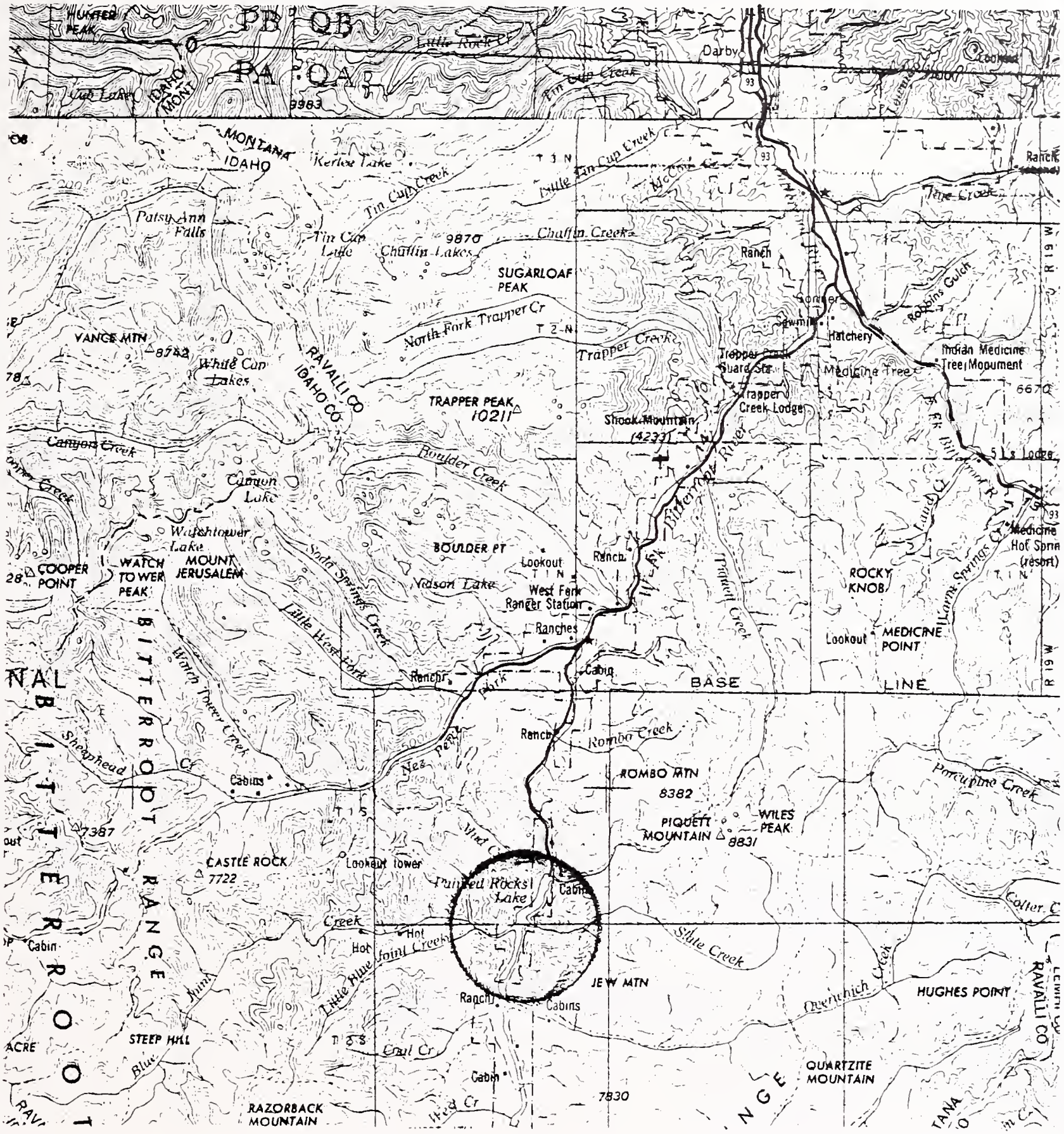
(PHOTO 5) DOWNSTREAM EMBANKMENT SLOPE

(PHOTO 6) UPSTREAM EMBANKMENT SLOPE AND OUTLET CONDUT INTAKE STRUCTURE



(Photo 7) LEFT ABUTMENT CONTACT (FROM CONSTRUCTION PHOTO)

(Photo 8) RIGHT ABUTMENT CONTACT (FROM CONSTRUCTION PHOTO)



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N

PLATE 1

WEST FORK BITTERROOT (PAINTED ROCKS) DAM VICINITY MAP

CH2M HILL

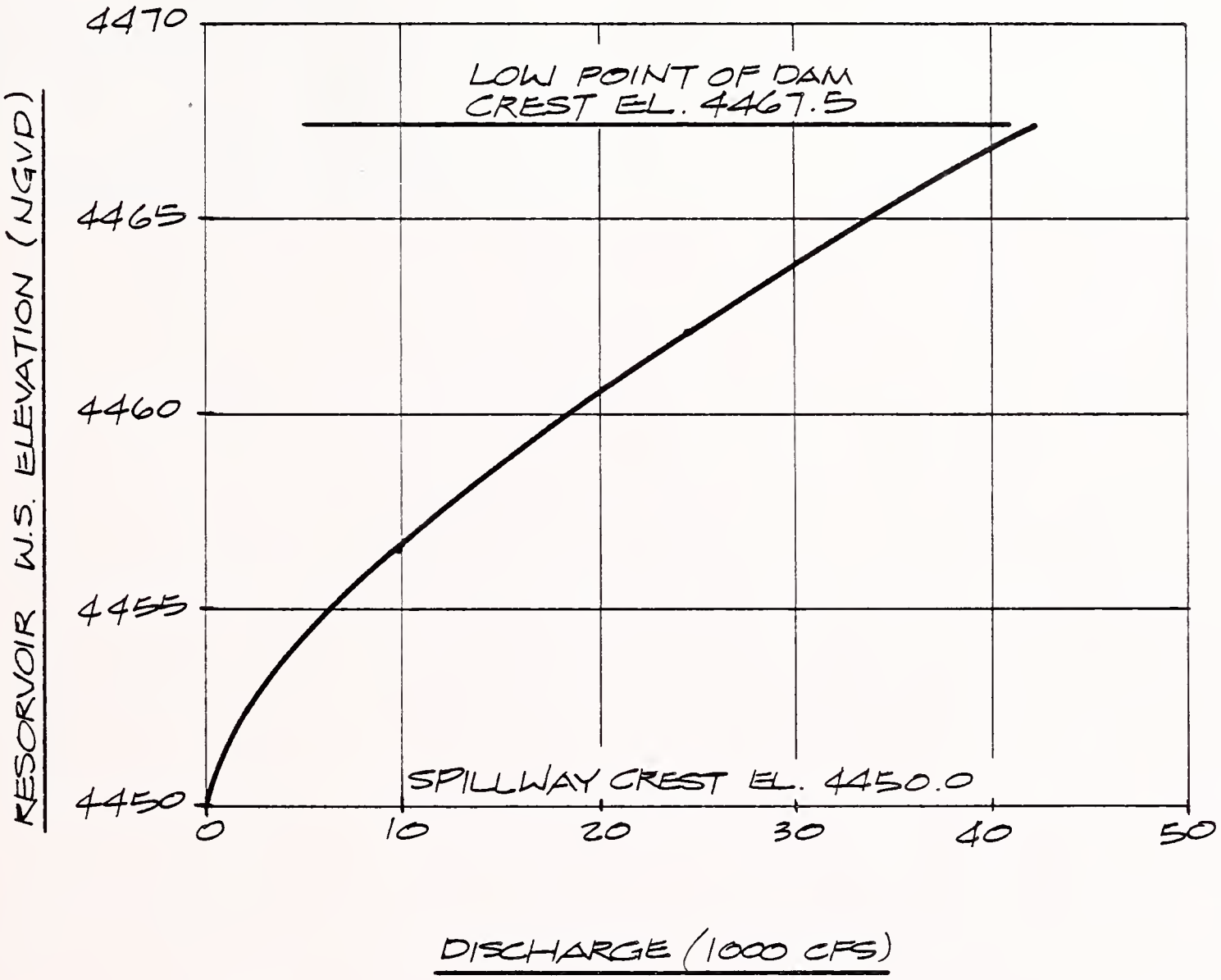
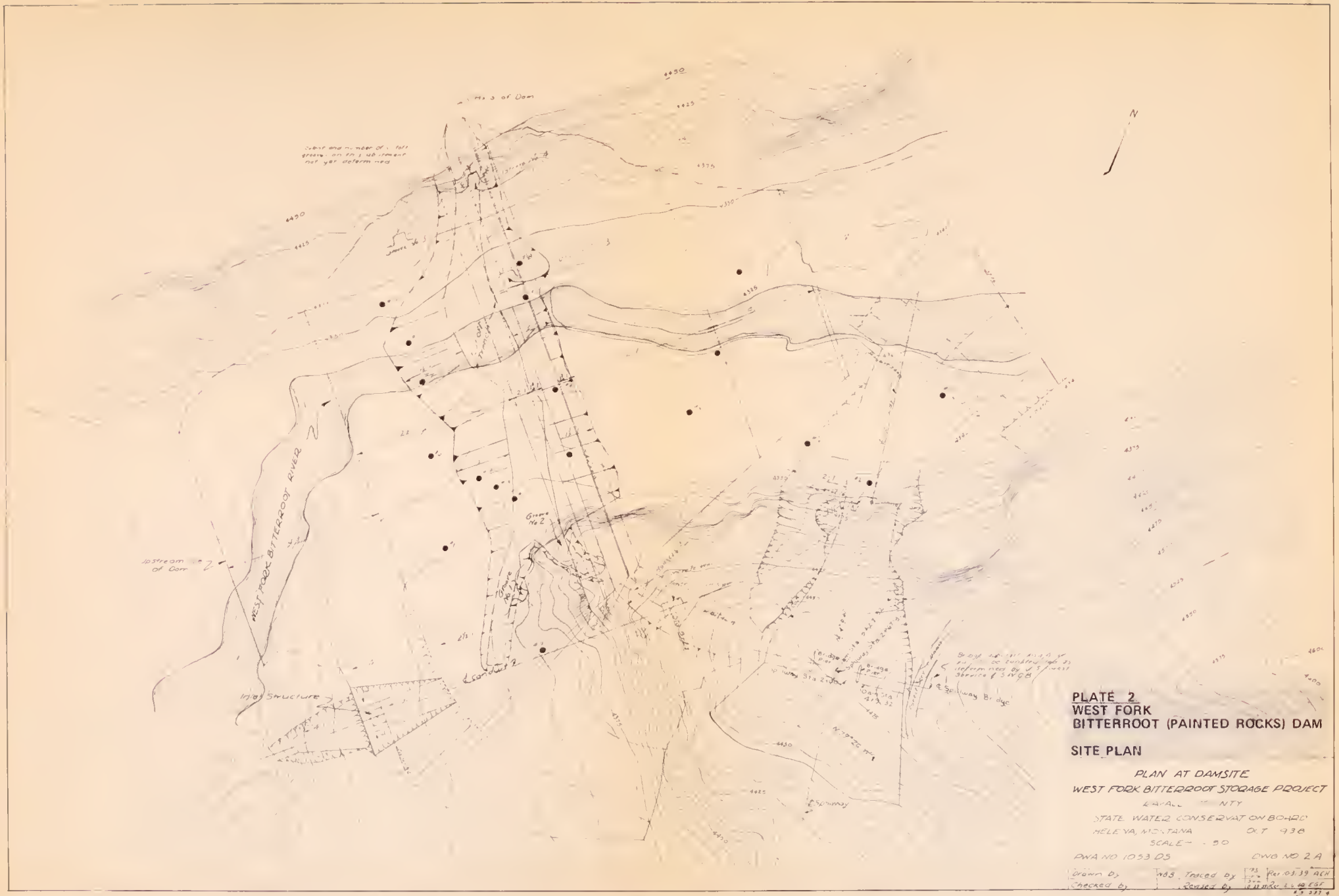


PLATE 5

WEST FORK BITTERROOT
(PAINTED ROCKS) DAM

SPILLWAY RATING CURVE

CH2M HILL


N
WEST FORK BITTERROOT RIVER
Upstream of Dam
Inlet Structure
Groove No 2
Groove No 1
Conduit 2
Spillway
Spillway Bridge
PLATE 2
WEST FORK
BITTERROOT (PAINTED ROCKS) DAM
SITE PLAN
PLAN AT DAMSITE
WEST FORK BITTERROOT STORAGE PROJECT
STATE WATER CONSERVATION BOARD
HELENA, MONTANA
OCT 1938
SCALE - 50
PWA NO 1053 DS
DWG NO 2 A
Drawn by
Checked by
Traced by
Revised by

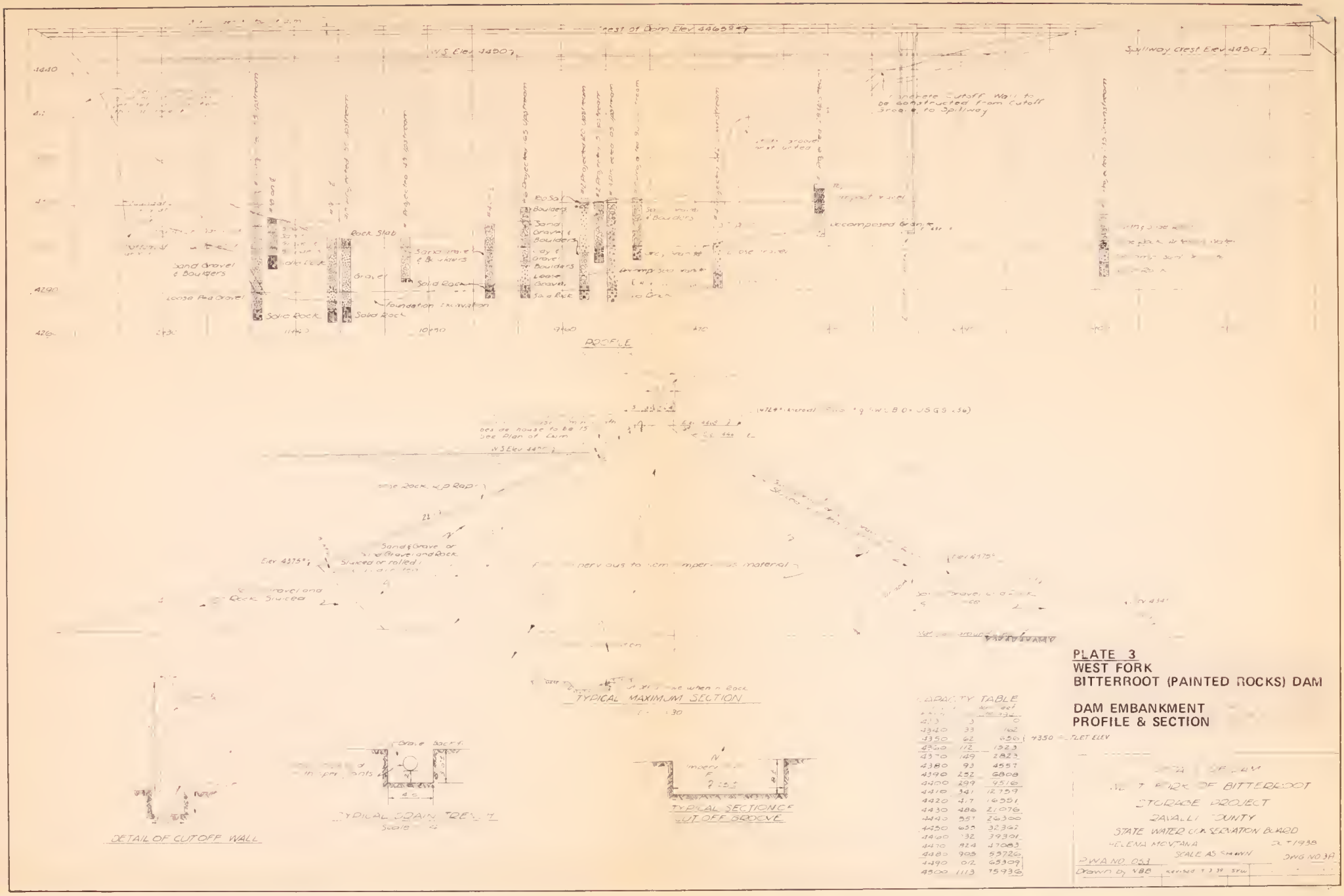


PLATE 3
WEST FORK
BITTERROOT (PAINTED ROCKS) DAM

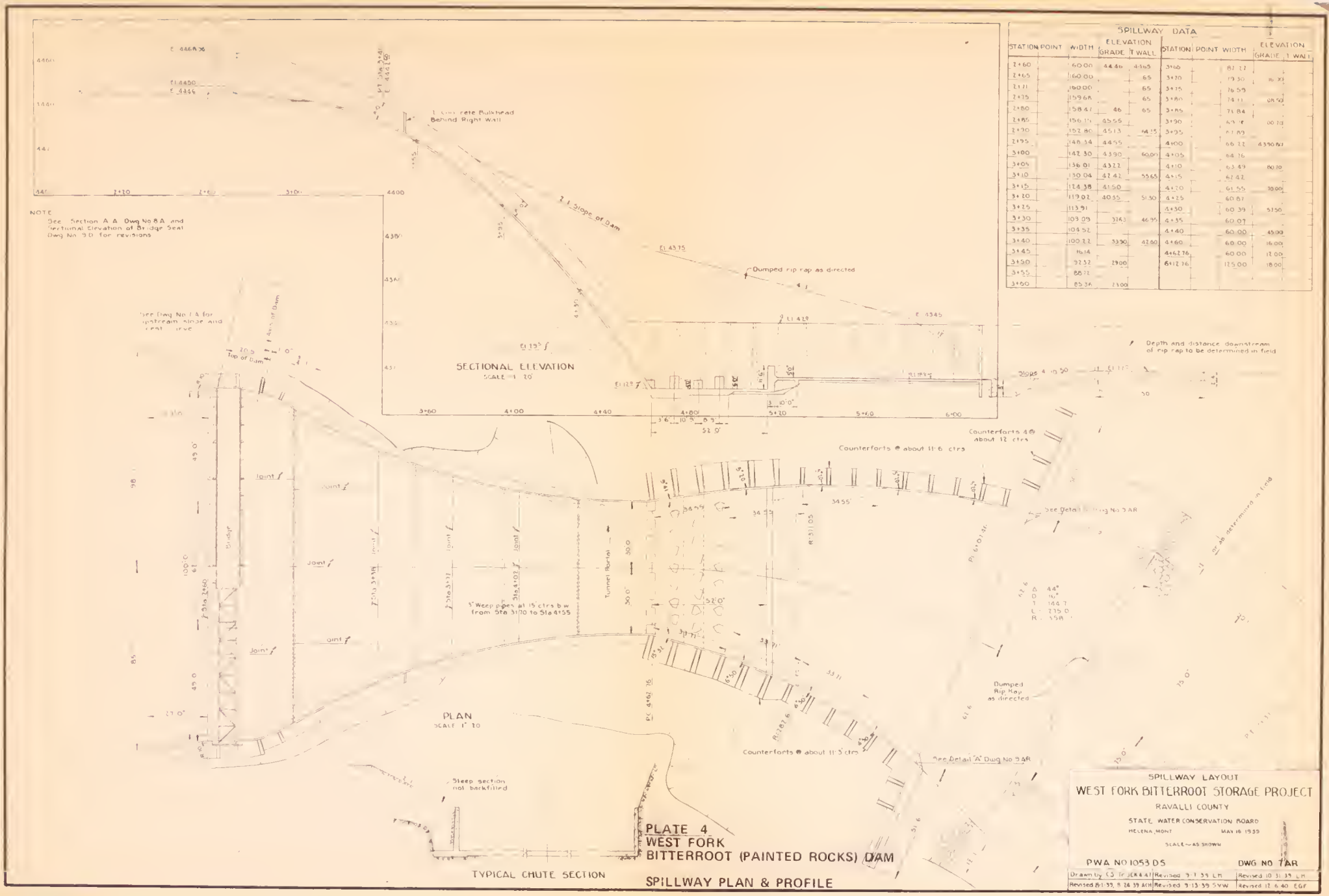
DAM EMBANKMENT
PROFILE & SECTION

CAPACITY TABLE

4330	3	0
4340	33	162
4350	62	656
4360	112	1523
4370	149	2823
4380	93	4557
4390	252	6808
4400	299	9516
4410	341	12759
4420	417	16551
4430	486	21076
4440	557	26300
4450	655	32362
4460	732	39301
4470	824	47083
4480	905	55726
4490	012	65309
4500	1113	75936

4350 OUTLET ELEV

WEST FORK OF BITTERROOT
STORAGE PROJECT
RAVALLI COUNTY
STATE WATER CONSERVATION BOARD
HELENA MONTANA
OCT 1938
SCALE AS SHOWN
DWG NO 3A
PWA NO 053
Drawn by NBB

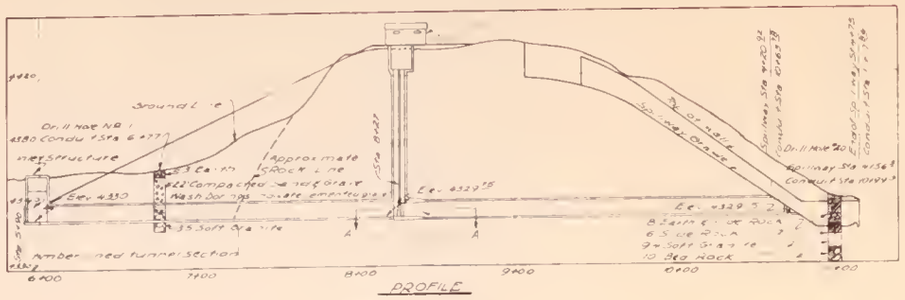


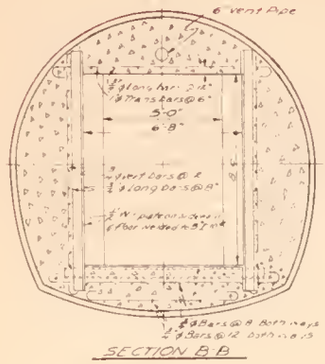
SPILLWAY DATA

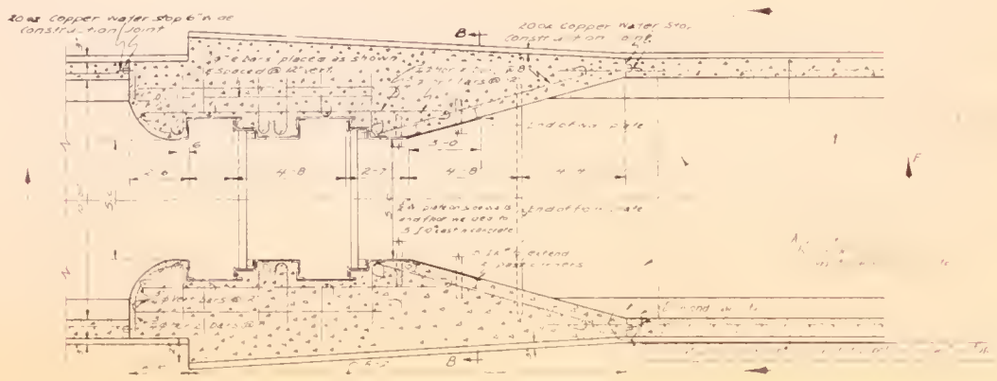
STATION	POINT	WIDTH	ELEVATION GRADE	ELEVATION T WALL	STATION	POINT	WIDTH	ELEVATION GRADE	ELEVATION T WALL
2+60		60.00	44.46	44.65	3+65		87.27		
2+65		160.00		65	3+70		79.30	16.30	
2+71		160.00		65	3+75		76.59		
2+75		159.68		65	3+80		74.11	08.50	
2+80		158.47	46	65	3+85		71.84		
2+85		156.15	45.55		3+90		69.18	00.70	
2+90		152.80	45.13	64.15	3+95		67.89		
2+95		148.34	44.55		4+00		66.22	43.90.80	
3+00		142.30	43.90	60.00	4+05		64.76		
3+05		136.01	43.22		4+10		63.49	80.70	
3+10		130.04	42.42	55.65	4+15		62.42		
3+15		124.38	41.50		4+20		61.55	70.00	
3+20		119.02	40.35	51.30	4+25		60.87		
3+25		113.91			4+30		60.39	57.50	
3+30		109.09	37.63	46.95	4+35		60.07		
3+35		104.52			4+40		60.00	45.00	
3+40		100.22	33.90	42.60	4+60		60.00	16.00	
3+45		96.14			4+62.76		60.00	12.00	
3+50		92.32	29.00		6+12.76		125.00	18.00	
3+55		88.72							
3+60		85.36	23.00						

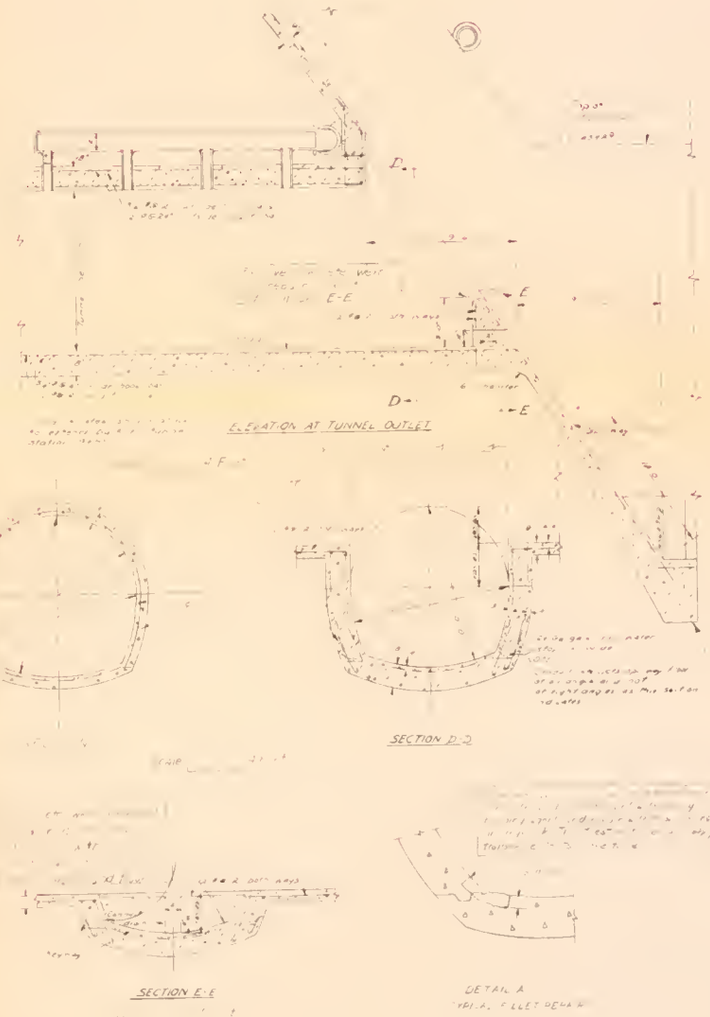
PLATE 4
WEST FORK
BITTERROOT (PAINTED ROCKS) DAM

SPILLWAY PLAN & PROFILE









NOTES

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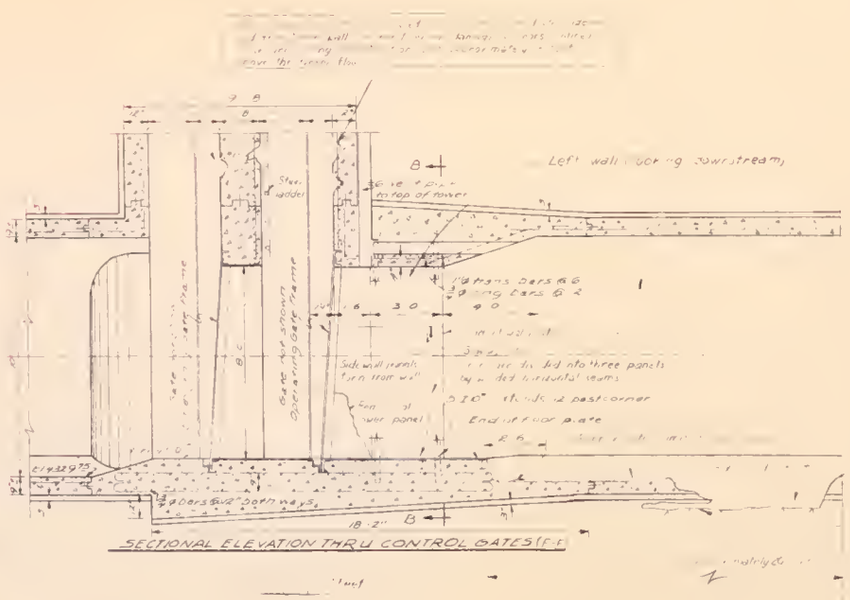

PLATE 6
WEST FORK
BITTERROOT (PAINTED ROCKS) DAM
OUTLET WORKS

MONTANA PROFESSIONAL ENGINEER'S LICENSE Nº 4917 E

JACK C JONES

DATE	LETTER NO.
DWG. TRANSMITTAL	

	BY	DATE	CHKD.	DATE
DSGN	DRB	8/76	JTP	8/76
DWN.	DRB	8/76	JTP	8/76
DIV	GROUP LDR	DEPT HEAD	DIV HEAD	BR HEAD
CIVIL		JTP		
MECH				
ELECT				
PLAN				
STAFF				CH. ENGR.

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

PAINTED ROCKS DAM OUTLET | MODIFICATIONS

EXISTING CONDITIONS AND LOCAL REPAIRS

HARZA ENGINEERING COMPANY

APPROVED [illegible]

CHICAGO, ILLINOIS | DATE SEPT 1976 | DWG NO 946 G-2

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD	APPD.